THE APPLICATION OF TELEMEDICINE TO IMPROVE MEDICAL DIAGNOSIS: A PILOT STUDY AT WILMER EYE INSTITUTE TO EXAMINE THE IMPACT OF TELEOPHTHALMOLOGY ON RESIDENTS' EDUCATION

by
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ABSTRACT

Background and Objective:

In this pilot study, we present our institution's initial experience with a teleophthalmology tool for use by ophthalmology residents during Emergency Department (ED) consultations. The specific objectives of this pilot study were to determine the initial logistics of incorporating a teleophthalmology device in residents' education and the residents' clinical workflow in addition to baseline measurement of the ophthalmic diagnoses for which the teleophthalmology device was most useful.

Methods:

The pilot study was carried out at Johns Hopkins Hospital Wilmer Eye Institute Emergency Department. Ten first-year ophthalmology residents were trained on the use of the device in capturing optical coherence tomography (OCT) images and photos of the retina in patients presenting to the ED with urgent ophthalmic concerns. Findings were communicated to the supervising ophthalmologist to make the final diagnoses. A retrospective chart review was conducted to collect patient characteristics and demographics. Residents rated ease of use, technical reliability, and educational value through a survey.

Results:

Recruitment for this project started on December 1, 2019, and ran through December 1, 2020. The Topcon device was used to capture 887 images (mean 8.1 images per encounter). Patients in our cohort were mostly female 65 (60%), with a mean age of 48.5 years. The most common reasons for urgent ophthalmic visits were papilledema (n=21,18.6%), new onset visual acuity or visual field defects that did not lead to a definitive clinical diagnosis (n=12, 10.6%). The mean quality of the image was rated 1.79 out of 3 by two independent graders. Eight residents completed the survey, and most (n=7) agreed or strongly agreed that the device helped them diagnose patients more accurately.

Conclusions:

The teleophthalmology tool in our pilot study was utilized most often in the assessment of papilledema. This tool was perceived by residents as beneficial in their education and enhanced diagnostic accuracy. To maximize the usability of this technology, steps must be taken to resolve the technological obstacles. These findings could be useful in guiding other specialties as they start to implement telemedicine programs and evaluate residency education programs.

Thesis Advisors: Dr. Harold P. Lehmann MD, PhD; Dr. Fasika A Woreta MD, MPH

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IN THE NAME OF ALLAH, MOST GRACIOUS, MOST MERCIFUL

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION AND BACKGROUND

1.1 Telemedicine History

Providing high-quality health care to everyone is one of the great challenges that society faces today. The World Health Organization (WHO) has conveyed this vision in its "Health for All in the 21st Century" strategy.[1] Barriers to achieving this vision are pressures levied by old and modern diseases on an increasing global population, rising health care costs and socioeconomic standards, which increase health inequalities within countries. To date, part of the challenge in achieving equal access to health care services has been the need for the physician and patient to be present in the same setting. However, the recent evolution of information and communication technology created significant opportunities to obviate the need for physical co-presence by increasing the number of ways in which health care can be provided. This solution can apply to developing countries with poor or fragile economies as well as developed nations. The opportunities for the use of information and communication systems to enhance the quality of health care are rapidly understood and accepted. The importance of using health information technology (IT) solutions to improve healthcare accessibility was described by the WHO in its Health-for-All strategy, which states the need to “integrate the appropriate use of health telematics in the overall policy and strategy for the attainment of health for all in the 21st century. This fulfills the vision of a world in which the benefits of science, technology, and public health development are made equitably available to all people everywhere."[2] Telemedicine, the field where healthcare and information telecommunications technologies intersect, is possibly a part of this revolution that will greatly affect health care delivery.[3]

Realizing that telemedicine does not have one definitive description—a 2007 study found 104 peer-reviewed definitions of telemedicine[4]—the following general definition has been adopted by the WHO[5]:

> "The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for the diagnosis, treatment, and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities."

The past 20 to 30 years have seen the most significant adoption of telemedicine, concurrent with developments in information technology. However, if telemedicine is considered to be any diagnostic activity conducted remotely, regardless of how the information is delivered, the history of telemedicine is much older. The innovator of the electrocardiograph, Willem Einthoven, first began experimenting in 1906 with remote consultations over the telephone, which was invented 30 years earlier. The concept of telemedicine was introduced by Drs. Kenneth Bird and Thomas Fitzpatrick of Massachusetts General Hospital (MGH) in the late 1950s. At Boston's Logan Airport, the doctors created a microwave video and closed-circuit television connection between MGH and a health care station. At that time, radiological and dermatological images, telepathology, cardiac auscultation and physical diagnostics were successfully transmitted between the two sites.[6]

1.2 Telemedicine and the COVID-19 Pandemic

The pandemic has only accelerated the prior growth in adoption of telemedicine. The new coronavirus (COVID-19) is a novel infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The contagious nature of COVID-19 makes the use of telemedicine highly valuable as it avoids the risk of spread by contact. The need for telemedicine to maintain social distancing and to mitigate viral spread is anticipated to increase in the light of the Covid-19 pandemic, and the transition to telemedicine poses a need to provide education to physicians who are unfamiliar with this mode of treatment.[7,8]

Adoption of telemedicine was growing already before the COVID-19 pandemic. The proportion of U.S. hospitals who communicate with patients through the use of video and other technologies rose from 35 percent to 76 percent from 2010 to 2017 (**Figure 1**).[8] There was significant growth in the adoption of telemedicine between 2004 and 2017. The bulk of the growth was due to an increase in primary care and mental health programs, with other specialties reporting only modest utilization.[9,10] Telemedicine is rapidly becoming more mainstream and will likely impact the way in which many physicians practice medicine going forward. The growing mobile healthcare industry is also affecting the growth of telemedicine today. Even before the COVID-19 pandemic, the wide variety of consumer-friendly mobile health applications and modern mobile medical technologies encourage patients to use technology to control and manage their health. The pandemic has only accelerated the adoption of telemedicine, and phone and video visits have constituted the majority of clinical contact in the past year.

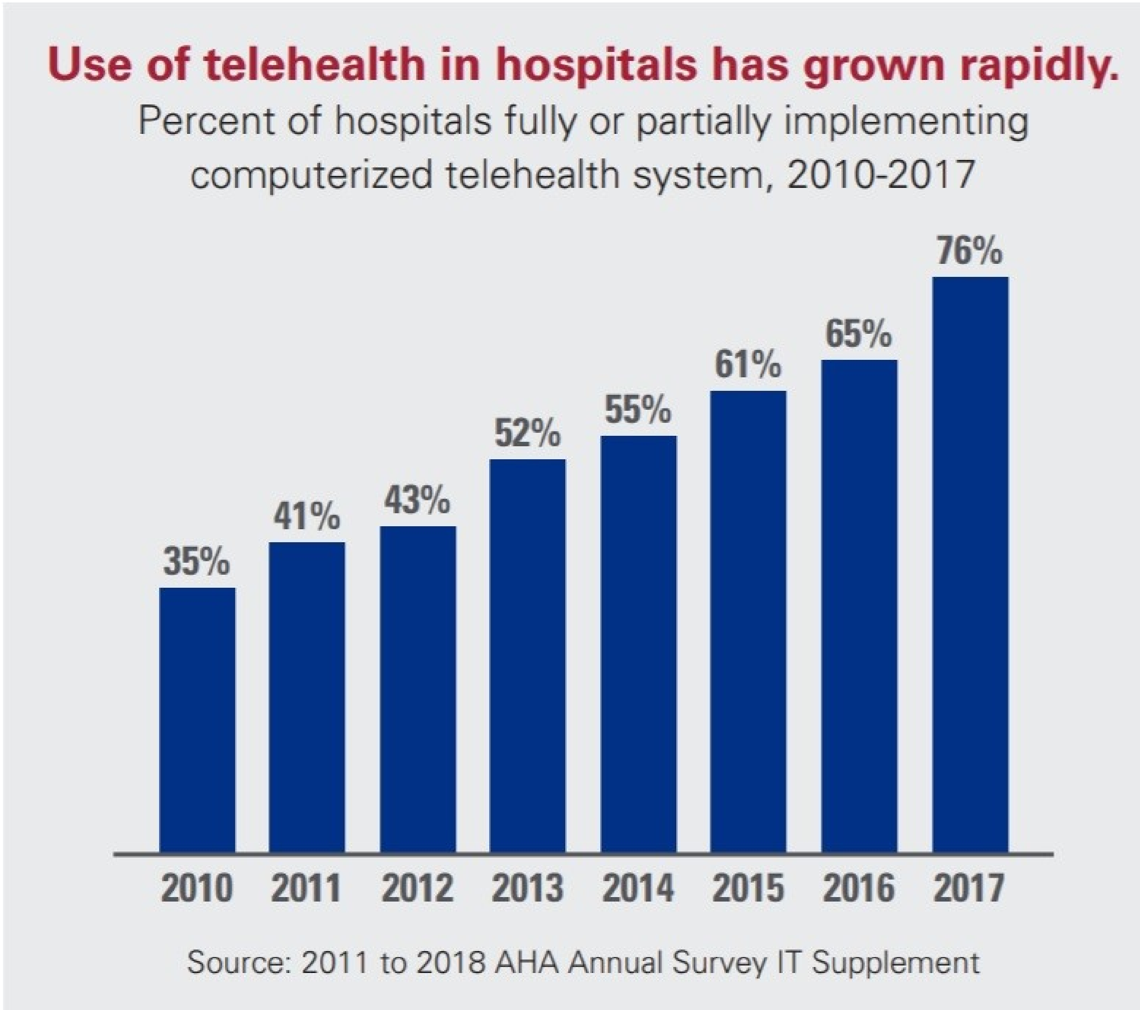


Figure 1: Percent of hospitals fully or partially implementing a computerized telehealth system, 2010 to 2017.

Before the COVID-19 pandemic, Medicare only reimbursed physicians for telehealth services, such as routine visits under certain conditions. For example, the recipient who receives the services should live in a rural area and travel to a local healthcare center to receive telehealth services from a physician in a remote site. In addition, the beneficiary generally could not get telehealth services in their home.[11] The COVID-19 pandemic has led to an extraordinary transition in operational processes, forcing doctors and health care systems around the world to rapidly adopt telemedicine solutions to limit or eliminate in-person visits.[12] During the coronavirus pandemic response, the U.S. government eased telehealth restrictions and provided resources to improve telehealth programs and reduce the risk of infections.[13] One of the main improvements to Medicare has been the removal of geographical restrictions on the location of patients, allowing telemedicine coverage to open to Medicare recipients living outside underserved rural communities. Effective March 6, 2020, Medicare allowed patients to access telemedicine programs regardless of geographical location and with no need to leave their homes to visit a physical location, such as a hospital or clinic.[14]

Due to these new changes, telemedicine adoption has rapidly increased the delivery of care for both follow-up and new clinic patients.[15] At Ohio State University-Wexner Medical Center, over the span of one week, the number of telemedicine visits increased from fewer than 100 visits a day to well over 2,200 per day (**Figure 2**).[16]

Healthcare leaders now need to figure out how to accommodate clinical care to the telemedicine reality. The massive transition to telemedicine across the U.S. has shown its efficacy as an important method in clinical settings.[7] The question facing telemedicine is what medical practice will be after the pandemic. We need to learn from our current interaction within the telemedicine environment and, more generally, through practitioners, decision-makers, health care policies, payers, academics, and society at large.[7]

Dr. Rashid Bashshur[7] highlights some lessons that we learned about telemedicine from the COVID-19 pandemic:

- A large percentage of physician's visits can be successfully handled clinically from a distance in diverse contexts (e.g., patients with non-urgent problems can be triaged to a telemedicine infrastructure without affecting their health or quality standard of care).

- The appropriate communication method is readily accessible at both ends of the healthcare practice, most easily via a smartphone.

- With minimum delays or dislocations, the required resources can be created accordingly, including the necessary preparation of appropriate manpower and workflow.

- As it is protective for caregivers and patients, little to no opposition can be seen against telemedicine. The most important aspect is the reimbursement process.

- All stringent telemedicine implementation rules, including interstate licenses, data confidentiality concerns, and, most importantly, reimbursement, have been eased by the government.

Out of this pandemic, the national healthcare sectors have been afforded a unique opportunity to examine their effectiveness, analyze vast implementation outcomes and maximize the utilization. Large implementation of telemedicine should be seen as a subsequent experiment.[7]

There are other factors that healthcare professionals need to consider when accommodating clinical care to the telemedicine reality. The pandemic has highlighted issues around limited access to services by certain demographic groups, inconsistent quality of services and increasing costs in our health care systems. In addition, having a reliable Internet connection, which is crucial to virtual visits, has emerged as its own social determinant of health.[17] In a 2015 report from the Pew Research Center, 15 percent of U.S. households did not report any type of internet availability; Black Americans were 12 percent less likely than Whites to have high-speed broadband service.[18] The end of the pandemic does not mean the end of these issues. Whereas telemedicine has been recognized as an appropriate means to maintain the healthcare system during the pandemic, legislators at different levels still have to truly comprehend how to leverage this potential in normal times.[18]

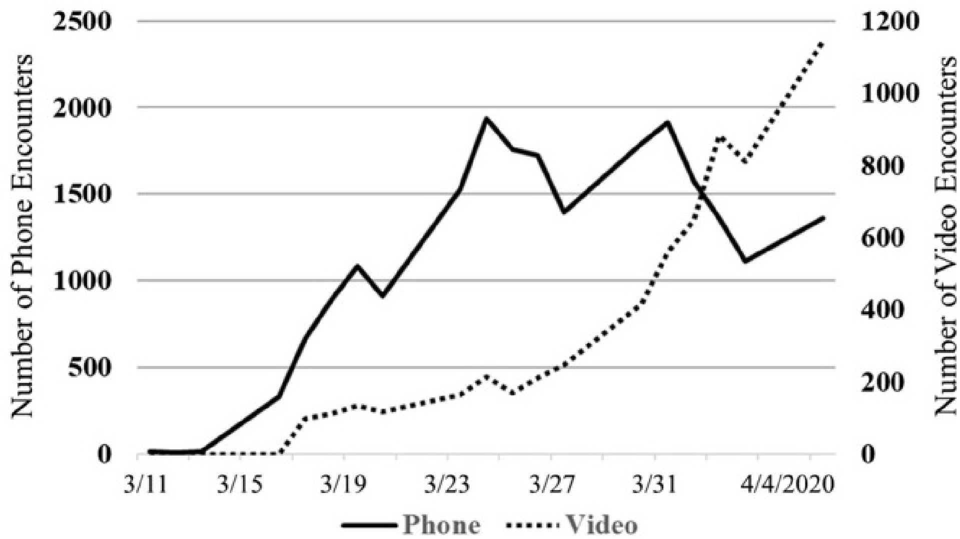


Figure 2[17]: Telemedicine use in response to the COVID-19 pandemic in 2020. In response to COVID-19, the use of telemedicine at The Ohio State University Wexner Medical Center increased from less than 100 visits per day to more than 2200 over a period over 24 days.

1.3 Emergency Department (ED) Overcrowding

Telemedicine has a specific relationship with emergency care, primarily around overcrowding. Emergency department overuse has been a significant concern worldwide in the last two decades.[19] The National Emergency Department Report found that annual ED visits rose from 89.6 million to 139 million between 2006 and 2017, an increase of 55.13%.[20,21] Uscher-Pines and colleagues[22,23] reported in a 2012 systematic review that nearly 40% of all ED visits were for non-urgent medical conditions.

Emergency departments should strive to provide services during high-demand periods and adapt to unplanned changes (e.g., a seasonal spike in demand) and unpredictable changes (e.g., unexpected accidents and increasing demand).[24] Emergency department overuse, however, hinders the ability of ED professionals to provide a prompt, safe, and reliable treatment, which increases the number of time patients spent in the ED (length of stay) and negatively affects patient health outcomes.[25] Length of stay in the ED is associated with higher seven-day mortality rates.[26]

According to Krochmal et al.,[27] patients who remain in the ED one day after admission generally have a longer average length of stay by 10–13% than patients who are immediately moved to inpatient units.

Non-urgent medical visits contribute to ED overcrowding, which may lead to delays in the treatment of other patients with more urgent health conditions.[28,29] Emergency department overcrowding also may lead to increased medical errors.[30]

According to the Joint Commission on Accreditation of Health Care Organizations, 50% of 'sentinel events' are reported in the ED, and one-third of these cases are due to overcrowding. Mortality cases also are increased in the ED as a natural consequence of overcrowding.[31,32] Cardoso et al.[33] report a 1.5% increase in mortality for each hour an ICU patient remains in the ED.

Identifying successful interventions that have proven to enhance care can support the uptake of those interventions or strategies in different contexts.[34] The use of telemedicine for screening ("tele-screening")[35] is a potential strategy to solve expanded ED demands. Via a real-time audio-visual interface for patients and remote care, tele-screening maximizes providers' time and possibly minimizes costly staffing needs.[35]

Traditionally, ED telemedicine was used to connect minor medical units to larger EDs and enable specialty consultation.[36] Telemedicine has the potential to effectively reduce ED overcrowding, minimize ED emergency transport, increase ED performance through incorporating specialized facilities, and reduce patient care costs.[37,38] On average, ED visits cost four times as much as office visits with similar medical conditions, the former of which resulted in $580 more per visit.[39]

Rademacher and colleagues[35] found that the use of telemedicine in ED for screening patients significantly decreased the number of patients left without being seen. A study conducted at Johns Hopkins Hospital[36] found that, "There was no difference in standard care received by patients with chest pain between tele-screening and in-person screening. Tele-screening was an effective and safe way for this ED to expand the hours in which a health care provider screened patients in triage." [40]

1.4 Telemedicine Cost-effectiveness Analyses

Patients in remote areas or crowded cities encounter financial obstacles to appropriate treatment, including high travel expenses due to long distance travel to receive medical services and time off of work, often requiring a whole working day for patients referred to a hospital.[41] On the other hand, medical centers experience big challenges in delivering more accessible medical services to rural patients. Some hospitals are seeking to recruit their full-time doctors directly, which could be costly for remote locations. The second solution is to set up a traditional on-site clinic run by a consultant who drives to and from a central practice. This strategy has drawbacks; the medical center would pay a premium to encourage physicians to travel to their remote areas.[41]

Telemedicine has been shown to reduce travel expenses for both time and money for patients. By making it easier for them to receive services, telemedicine has improved access for patients who would not normally be able to get care nor be seen in certain clinics.[42,43] Telemedicine can increase overall patient compliance and reduce the related financial burden of no-show visits to practices and clinics by mitigating and manage barriers to care.[17] At this time, cost-effectiveness evidence for the use of telemedicine is limited. However, new studies conducted in telemedicine in the pre-hospital care setting have recently demonstrated positive outcomes.[44,45]

Back in 2007, estimates anticipated that telemedicine could avoid the need for close to 850,000 hospital transfers and save US$537 million per year.[46] According to the University of California Davis, comparing telemedicine to in-person visits, an estimated average time savings of 245 minutes and average cost savings of $156 are made by using telemedicine visits.[43]

Studies to date indicate that there is a lack of concrete proof to adequately analyze the economic effect of telemedicine.[47] There are various costs involved in the integration and deployment of these technologies. Many of the expenses include but are not limited to the cost of equipment, training, and connectivity. Cost-utility analysis (CUA) and cost-effectiveness analysis (CEA) are two of the most popular economic assessment approaches. The CUA is seen generally in the evaluation of health technologies. The key goal of CUA is to calculate the ratio between the cost of the clinical-related intervention and the value it provides in terms of the number of years that consumers have remained in full health. Cost-effectiveness analysis, which is comparable to CUA, is typically used as a calculation of the ratio where the denominator is a health benefit from the measure (e.g., years of life) and the numerator is the cost associated with the health benefit.[48,49,50]

Johnston et al.[51] found that teleophthalmology was cost-effective in minimizing the burden of eye problems and that physicians in South Africa have learned innovative techniques that could benefit prospective patients and maximize cost-effectiveness. He also mentioned that telemedicine technology is a cost-effective approach that richer nations should use to help build infrastructure in poor countries' health care systems. Aoki et al.[52] performed a CEA analysis to examine the medical and economic effect of teleophthalmology in the diagnosis of diabetic retinopathy in prisoners with type 2 diabetes. He reported that cost-effectiveness evaluation indicates that teleophthalmology is promising to decrease the cost of prisoner treatment and minimize blindness caused by diabetic retinopathy. Another teleophthalmology cost-effectiveness seven-year study performed by Levin et al.[53] reports that teleophthalmology remote consultations for diabetes management are feasible and that the interdisciplinary approaches have produced high treatment standard-of-care outcomes. In addition, telemedicine deployment was correlated with improved cost effectiveness and patient satisfaction.[53]

1.5 Medical Diagnosis Accuracy and Residency Education

While the focus so far has been on clinical care, it is important to consider the impact of telemedicine on the second "leg" of academic medicine: Education. In image-oriented fields like ophthalmology, cardiology, dermatology, and radiology, teaching and learning related to diagnostic assessments is based on photographs captured by residents/technicians.[54] Thus, remote diagnosis using telemedicine should be an effective strategy for teaching and learning in image-oriented specialties.[55,56]

Central to teaching around such images is the accuracy of even the best diagnosticians in using photographs. Almost all published research investigating the accuracy of photo-related telemedicine tools has analyzed their performance compared to a gold standard of assessment by an expert doctor. However, it is not certain that the accuracy of in-person assessments is inherently superior to that of photos reviewed by a remote physician. Teleophthalmology can generate the same clinical outcomes as conventional, in-person examination.[57] It is important to consider the factors leading to a successful diagnosis and to provide a clear definition of the correct diagnosis to determine the effectiveness of telemedicine tools.[58] Although several studies have addressed the efficacy of telemedicine, there is still limited literature on the diagnostic accuracy of telemedicine-based screening.[59]

Using stereoscopic fundus photography, a systematic review by Ullah and colleagues[59] showed a sensitivity of 87% and 91% specificity for the absence of retinopathy, although there are extensive differences in these values for the diseased retina. It is highly specific for diabetic macular edema, clinically significant macular edema, proliferative diabetic retinopathy, and severe non-proliferative diabetic retinopathy. However, the considerably lower cost of teleretinal screening makes for an advantageous platform for both image capture, storage, analysis, and transmission compared with conventional screening. In addition, tele-screening also improves screening compliance and may prevent blindness in a significant portion of the population that would otherwise not have been reached.

Telemedicine can play several roles in resident education. First, it allows residents to discuss cases with their attendings or consultant remotely, but synchronously, whether as part of routine teaching or case-specific expert consultation. Advanced features such as optical coherence tomography (OCT) in the ophthalmology specialty add the potential for learning and consultation.

Beyond image-based practice, the Association of American Medical Colleges promotes telemedicine exposure during all residencies. Targeted goals include: promoting the acquisition of basic knowledge, improving decision-making, enhancing the understanding of differences in biology lectures or 3-dimensional simulations, optimizing coordination of skills, practicing for unusual or critical incidents, completing teamwork, and improving psychomotor awareness.[60] The pandemic has made each of these goals more salient. However, there is no acknowledged gold standard for graduate medical education.[61]

Both medical students and residents agree that experiences with telemedicine during their training serve as an important educational opportunity to help their knowledge of core competencies in practice-based education, clinical skills, and patient care.[62]

The new generation of medical students and residents have grown up in a technology- and computer-oriented era. Their knowledge of technology must be developed in an academic environment to ensure that they acquire the skills required to integrate telemedicine into their work.[62] However, today, medical students lacking formal telemedicine education tend to feel incompetent to use telemedicine and say that they are unfamiliar with telemedicine regulatory policies.[63]

2. METHODS

2.1 Aims and Outcomes

In the United States, teleophthalmology is expanding rapidly and has been shown to enhance access to healthcare, outcomes, and patient experience.[38] The use of teleophthalmology among ED ophthalmology residents to enhance resident education has not been well investigated. The specific objectives of this pilot study were to **determine the initial logistics of incorporating a teleophthalmology device in resident education and the residents' clinical workflow. That is in addition to the baseline measurement of ophthalmic diagnoses for which the teleophthalmology device was most useful**. A secondary objective of this study was to **determine best practices that may be effective in training non-ophthalmology residents in this technology, as well optimal implementation of this technology in other academic hospitals, non-academic hospitals, and outpatient clinics more broadly.**

In this preliminary study, we present our institution's initial experience with a teleophthalmology tool for use by ophthalmology residents to share examination findings and images with supervising ophthalmologists during ED consultations.

Research question:

We assume that this new technique will enable residents to conduct posterior segment ophthalmic imaging in the ED that can be quickly and asynchronously shared with supervising ophthalmologists. As a result, we hypothesize that residents will experience greater self-reported learning. We wanted this pilot study to answer the main question: is this teleophthalmology device feasible to use in resident education to increase residents' learning in the ED?

Aims:

Aim 1. To identify **the most common causes of consults** to the ED for urgent eye-related concerns.

-Hypothesis 1. Many ophthalmic visits in the ED are nonemergent.

Aim 2. To evaluate the **effect of implementing teleophthalmology in the ED on resident education.**

-Hypothesis 2: Implementation of teleophthalmology in the ED will improve resident education and knowledge and improve diagnostic accuracy for ED consults performed by ophthalmology residents.

Anticipated outcomes:

The primary outcome(s) for the target study will be the **frequency of diagnoses** for visits the teleophthalmology (Topcon) device was used for and resident feedback of the device's educational utility. Secondary outcomes are **the image quality ratings** and **residents' evaluation of device features**, such as **technical robustness** and **ease of use**. We believe that this teleophthalmology pilot study will enable us to determine the sample size needed for a larger target study. We also believe it will allow us to obtain more information on the feasibility of using teleophthalmology during residents' ED consultations and to improve the learning outcomes in our local residency program as well as other residency programs.

2.2 Clinical Setting

The pilot study was conducted at the Johns Hopkins Hospital (JHH) ED (Baltimore, MD, USA). The JHH ED serves a wide range of patients, playing a crucial role in the Johns Hopkins health care system's missions of patient care, education, and research. As such, nationally and globally, the Department of Emergency Medicine is known for quality in patient care and advanced technologies.[64] The pilot intervention was initiated in December 2019 and completed in December 2020. The pilot study was approved by the Institutional Review Board (IRB) of the Johns Hopkins University School of Medicine (IRB00209113 and IRB00256929). The online survey was reviewed by the IRB and deemed exempt from IRB approval. All study activities were conducted according to the principles of the Declaration of Helsinki[64] and all applicable local and national privacy laws (such as the Health Insurance Portability and Accountability Act)[65] and institutional policies and guidelines.

The intervention was carried out by first-year ophthalmology residents from the Wilmer Eye Institute (WEI). The WEI residency program was recognized as the top overall program in the nation in the year 2020 in terms of ophthalmic research, training five resident physicians per year. Surgeons at WEI perform more than 15,000 surgeries a year and treat more than 270,000 patients.[66] The WEI Eye Trauma Center is located in the ED at the JHH and is a designated eye trauma center in the region.

2.3 Eligibility Criteria

Patients were eligible for the study if they were 17 years or older and had presented to the ED for an eye-related chief complaint or diagnosis where posterior segment imaging was clinically indicated.

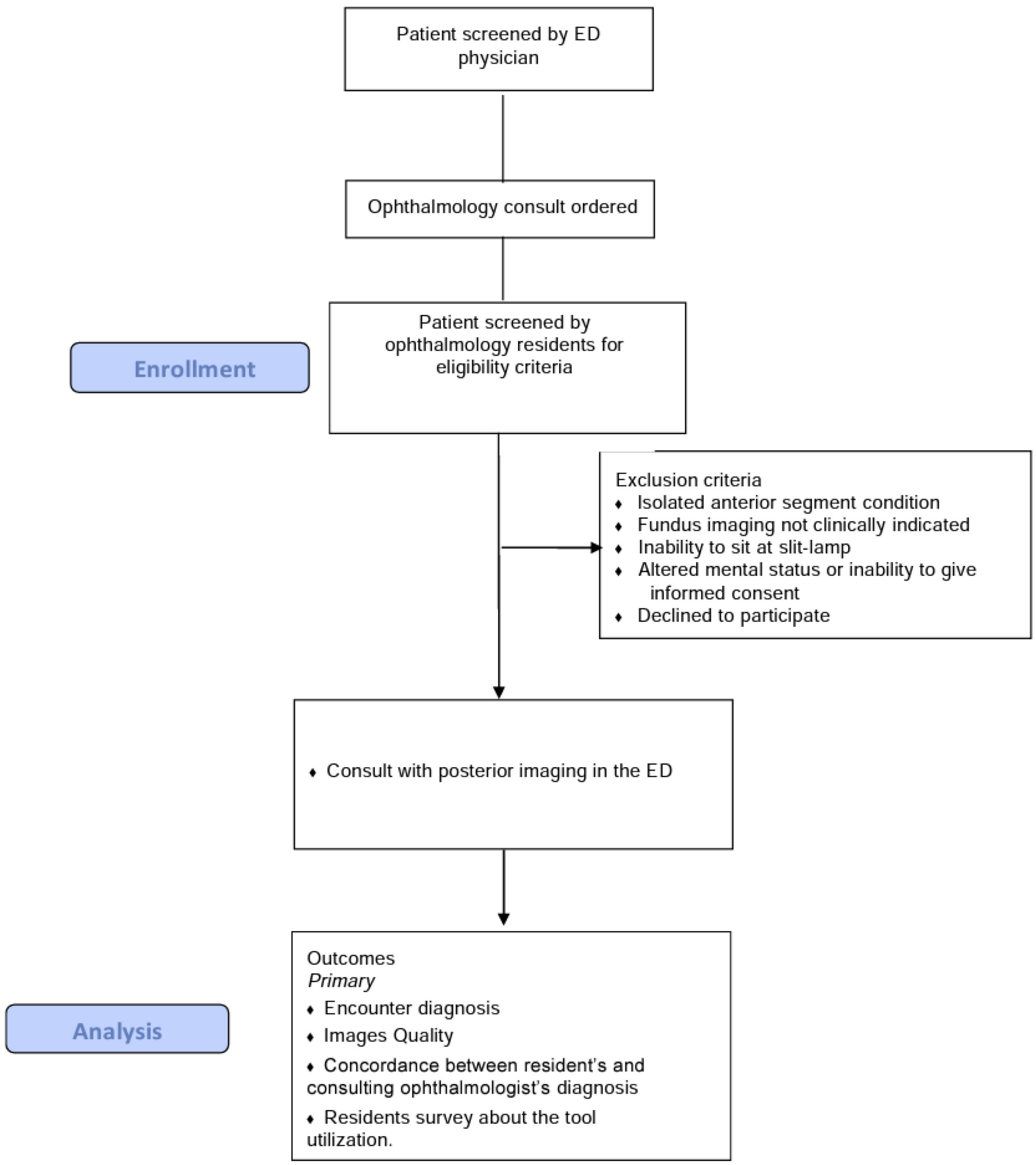
Study exclusion criteria were patients less than 17 years of age; patients with an isolated anterior segment condition; fundus imaging not clinically indicated for patients; patients with an inability to sit at slit-lamp; altered mental status or inability to give informed consent to patients; and patients who declined to participate. The IRB granted a waiver of informed consent due to the fact that inclusion of the teleophthalmology device was standard of care and provided minimal identifiable risk to the patient.

2.4 Study Design

The pilot study was divided into two parts. The first part was a retrospective analysis of all patients who underwent imaging by an ophthalmology resident physician using the Topcon 3D OCT-1 Maestro System (Topcon Medical Systems Inc., Oakland, NJ, USA) between December 1, 2019 and December 1, 2020 at the JHH. The first part of the study was conducted to identify the most common reasons for ophthalmology consultation and the patients' clinical characteristics. The second part of this study was to evaluate ophthalmology residents' experience using the Topcon 3D OCT-1 Maestro System. The survey of ophthalmology residents was conducted using an online platform (Qualtrics, Qualtrics® Software Company Provo, UT, USA, and Seattle, WA, USA) at two time points. We first distributed the survey in October 2020 with five residents who had just completed their first year of training. We distributed the survey at a second time point in February 2021 during which we interviewed five residents currently in their first year. The second part was conducted to evaluate and assess the value and effect of this tool on residents' education and knowledge.

Because the Topcon 3D OCT-1 Maestro System was acquired specifically for this study, the ophthalmology residents were first trained in the use of it to capture photos. Ten first-year ophthalmology residents were instructed on how to use the system to collect OCT images and photographs of the retina by the medical device representative. They were subsequently encouraged to use it in their assessments of patients with urgent eye problems who presented to the ED. Examples of images can be seen in **Figure 3**.

Intervention workflow:



The patient arrives at the ED with an “eye problem” as indicated by the chief complaint. The ED physician then screens the patient to validate the chief complaint. Once the ED physician confirmes the case, an ophthalmology consult order is sent to the resident who is on-call at that time. The ophthalmology resident then assesses the patient and determines whether or not to use the imaging system based on whether such images would be helpful for diagnosis and clinical management (such as measuring optic nerve thickness or documenting retinal lesions). After collection, images are exported to Zeiss Forum (Carl Zeiss AG, Oberkochen, Germany), which is an image storage and access platform utilized systemwide at WEI. Residents then communicate with the on-call supervising ophthalmologist to share their findings and discuss the images, which are available to both parties on Zeiss Forum. During our study, the supervising ophthalmologist was either an attending physician or a subspecialty fellow. Using OCT images, the resident coordinated with the on-call supervising ophthalmologist to make a final diagnosis and clinical management plan.

A retrospective chart review was performed to collect information on the demographics, visual acuity, time of visit to the ED, time of ophthalmology consult in the ED, final disposition, and final diagnosis or explanation for visit as recorded by the ophthalmology resident. Images were exported from the system using the Zeiss Forum and graded on a scale of 1 to 3 for image quality by two independent reviewers on a scale of 1 (lowest) to 3 (highest). A score of 1 indicated low quality with no or almost no findings observable (for example, an image with significant glare or visual artifact). A score of 2 indicated fair quality with observable findings, and a 3 indicated good quality with all observable findings. To compare the inter-rater reliability of image quality ratings, an intraclass correlation coefficient (ICC) was measured. An ICC of 0.5 to 0.75 was defined as moderate agreement, while a strong agreement was defined as 0.75 to 0.9.[67]

An anonymous survey was used to evaluate the effect of implementing teleophthalmology in the ED on resident education and on residents' self-perceived diagnostic utility of this device.

2.5 Data Management and Analysis

SAFE Desktop:

The Secure Analytic Framework Environment (SAFE) is a virtual desktop that provides Johns Hopkins Medicine investigators and researchers (whether engaged in research or other data-intensive activities) with secure access to a complete environment to analyze and share sensitive data (e.g., protected health information [PHI], personally identifiable information [PII]) with colleagues.[68]

The SAFE Desktop was used to manage and analyze this study data set.

Epic Electronic Health Records (EHR):

This study used Epic EHR data as the primary source for the retrospective chart review. The Epic EHR was used to obtain information on demographics, visual acuity, time of arrival to the ED, time of ophthalmology consult in the ED, the patient's final disposition, and final diagnosis as documented by the ophthalmology resident.

Topcon 3D OCT-1 Maestro:

The Topcon 3D OCT-1 Maestro was acquired by the WEI for the purposes of this pilot study. The device can capture full-color fundus photos as well as OCT scan images, encompassing both the macula and disc.[69] Optical coherence tomography is an imaging modality that provides ultrasound images of the retina, optic nerve, and optic disc. OCT is often used to image the eyes of patients with glaucoma. The device is capable of providing detailed imaging reports that can estimate the thickness and reference data for the retina and optic disc topography. The purpose of using this system is to provide additional imaging information to assist residents in their diagnostic process and to share the images with the on-call supervising ophthalmologist before making the final diagnosis.

Zeiss Forum:

Forum is an online platform from Zeiss that was used by the WEI as an ophthalmic data management solution. It connects ophthalmology devices and provides access to all images that are acquired by connected devices across the health system. In addition, ophthalmologists can access images remotely through a virtual private network (VPN) connection.

Zeiss Forum was used in this study to extract and analyze the patient images captured by Topcon 3D OCT-1 Maestro System.

Excel:

Microsoft Excel (Microsoft Corp, Redmond, WA, USA) software was used for data storage and cleaning.

Qualtrics:

We collected residents' feedback via an online survey delivered using Johns Hopkins installation of Qualtrics. All participants provided online consent before completing the questionnaire. The Qualtrics questionnaire was administered through email, and responses were anonymous.

3. RESULTS

Recruitment for this project started on December 1, 2019, and ran through December 1, 2020. At the beginning of the study, individual training and group training were conducted to ensure adequate knowledge of device use (**Figures 4, 5, and 6**).

Figure 4. Program Director Dr. Fasika A. Woreta, MD, MPH, training a resident on use of the non-mydriatic fundus camera with OCT capability.

Figure 5. The teleophthalmology device that was used in our pilot study is Topcon 3D OCT-1 Maestro System.

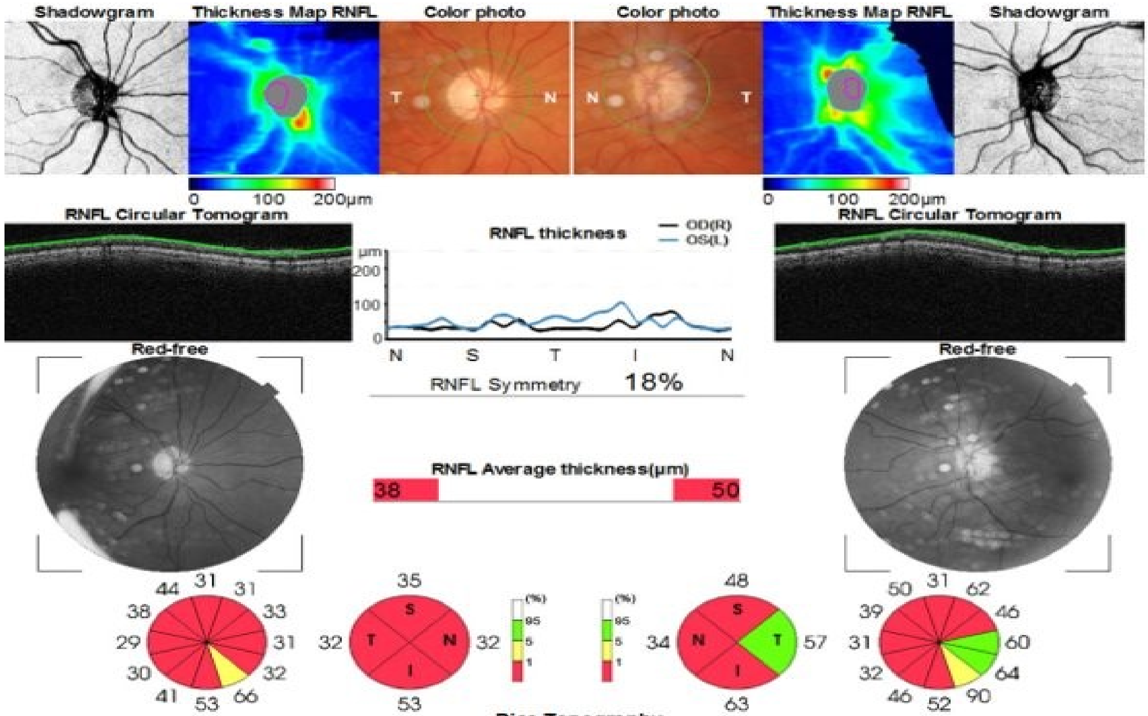


Figure 6: Report by Topcon with data analysis to help the resident to make a more accurate diagnosis.

3.1 Participant Demographics and Clinical Characteristics

The Topcon 3D OCT-1 Maestro device was used by 10 residents to evaluate 109 patient encounters (107 unique patients) out of a total of 1,715 ophthalmology consults in the adult ED during the study period. **Table 1** shows demographic and clinical characteristics of the 109 patients who presented to the ED. Patients in our cohort were mostly female 65 (60%), with a mean age of 48.5 years (range, 17 to 90 years; standard deviation [SD], 17.2). With respect to race, 47 (43.1%) patients reported that they were White, 42 (38.5%) reported that they were Black, 9 (8.3%) reported that they were Hispanic/Latino, 5 (4.6%) reported that they were Asian, and 1 (0.9%) reported that they were American Indian or Alaskan Native; 5 (4.6%) reported that they were “other”. The average logarithm of the minimum angle of resolution visual acuity was 0.50 (Snellen 20/63, SD 0.8, range 0 to 3).

The average length of stay (defined as either discharge from the ED, admission for ED observation, or admission to the hospital) for patients was 44.9 hours (SD 75.7, range 3.6 to 464.6). Patients were in the ED on average for 6.1 hours (SD 4.6, range 1.3 to 23.1) before they were screened by Topcon device. The average length of stay for patients imaged with the Topcon in the ED was 13.1 hours (SD 8.6, range 3.6 to 54.4). The average time from ophthalmology consult to ED discharge was 9.3 hours (SD 7.6, range 0.3 to 51.8). With respect to disposition from the ED, 73 (67.0%) patients were discharged, 14 (12.8%) were admitted, 14 (12.8%) were hospitalized for observation, 2 (1.8%) eloped, 2 (1.8%) were screened and left, 1 (0.9%) left against medical advice, 1 (0.9%) was sent to the ophthalmology department, and 2 (1.8%) patients’ dispositions were not available.

An average time of 7.9 hours from ophthalmology consult to ED discharge (SD 7.3 range 0.7 to 92.4) was observed in patients who were not examined with Topcon. Between patients that were and were not examined with the Topcon, the time from ophthalmology consult to ED discharge was comparable (9.3 vs. 7.9 hours, P = 0.07). Twenty-one patients (15.6%) were examined with Topcon for an assessment for papilledema out of 135 patients. There were no statistical differences between the patients who were examined by Topcon and those who were not in the length of the time between ophthalmology consult to ED discharge time (10.2 vs. 11.7 hours, P = 0.39).

Table 1. Patient and visit characteristics of patients presenting to the emergency department with urgent ophthalmic concerns and imaged by resident physicians with the Maestro 3D OCT-1 system from December 1, 2019 to December 1, 2020.

Patient Characteristics	
Patient encounters, n	109
Age, mean (SD), range	48.5 (17.2), 17-90
Female sex, n (%)	65 (59.6%)
Race, n (%)	
White	47 (43.1)
Black	42 (38.5)
Asian	5 (4.6)
Hispanic	9 (8.3)
American Indian or Alaskan Native	1 (0.9%)
Other	5 (4.6)
Visual Acuity, logMAR (Snellen), SD, range	0.5 (20/63), 0.8, 0-3
Average time in ED	13.1 (8.6), 3.6-54.4
Average length of stay (hours), mean (SD), range	44.9 (75.7), 3.6-464.6
Average time between Ophthalmology consult and ED discharge (hours), mean (SD), range	9.3 (7.6), 0.3 - 51.8
Disposition from ED, n (%)	
Discharge	74 (67.9%)
Admit	15 (13.8%)
Hospitalized Observation	14 (12.8%)
Eloped	2 (1.8%)
Left against medical advice	1 (0.9%)
Send to Ophthalmology Department	1 (0.9%)
Not Available	2 (1.8%)

n = Number of survey respondents
SD = Standard deviation
ED = Emergency Department

3.2 Utilization of Teleophthalmology for Medical Diagnosis

Table 2 summarizes the ophthalmic conditions and clinical diagnoses found in patients presenting to the ED with urgent ophthalmic conditions and who were imaged using the teleophthalmology Topcon device. The most common reasons for urgent ophthalmic visits were papilledema (n=21,18.6%), new onset visual acuity or visual field defects that did not lead to a definitive clinical diagnosis (n=12, 10.6%), retinal tears or detachments (n=8, 7.1%), traumatic eye injury (n=8, 7.1%), and autoimmune disorder and diabetic retinopathy visits (n=7, 6.2% for each). Other reasons for urgent ophthalmic visits accounting for fewer than 5% are listed below in Table 2.

Table 2. Diagnoses and reasons for evaluation of patients presenting to the emergency department with urgent ophthalmic concerns and imaged by resident physicians with the Topcon 3D OCT-1 Maestro system from December 1, 2019 to December 1, 2020.

Ophthalmologist Diagnosis or Reason for Evaluation	n (%)
Papilledema	21 (18.6)
New onset VA/VF defects	12 (10.6)
Retinal tear/detachment	8 (7.1)
Traumatic eye injury workup	8 (7.1)
Autoimmune workup	7 (6.2)
Diabetic retinopathy	7 (6.2)
Non-diabetic Retinopathy/Retinal lesion	5 (4.4)
Optic neuropathy	5 (4.4)
Mass/Tumor	5 (4.4)
Posterior vitreous detachment	4 (3.5)
Headache	3 (2.7)
Cataract	3 (2.7)
Macular pathology	3 (2.7)
Glaucoma	3 (2.7)
Infectious	3 (2.7)
Foreign body evaluation	2 (1.8)
Central retinal artery occlusion/Stroke	2 (1.8)
Carotid cavernous fistula	1 (0.9)
Cranial nerve palsy	1 (0.9)
Central retinal vein occlusion	1 (0.9)
Pterygium	1 (0.9)
Drug side effect evaluation	1 (0.9)
Internal carotid artery stenosis	1 (0.9)
Dry eyes	1 (0.9)
Choroidal neovascularization	1 (0.9)

n = Number of survey respondents
VA = Visual Acuity
VF = Visual Field

3.3 Image Quality Analysis

During the study period, the Topcon device was used to capture 887 images for the 109 patient encounters (107 unique patients). There were 8.1 images per patient on average. The average quality of the image was rated 1.79 out of 3 (1 the lowest to 3 the highest) by two independent graders. The image quality was graded subjectively by two independent researchers at WEI: 1. Michael J Fliotsos, M.D. (MJF) and 2. Yesha S Shah, B.S. (YSS). Grader 1 (MJF) had a 1.80 average image quality rating, while Grader 2 (YSS) had a 1.78 average image quality rating. By taking into account only the highest-quality image from each patient, the overall average image quality was 2.24 (Grader 1's average was 2.23; Grader 2, 2.26). The ICC was 0.75 (95% CI 0.72-0.78, $p<0.001$), in the accepted range of "moderate agreement." Examples of image quality are shown below (**Figures 7 and 8**).

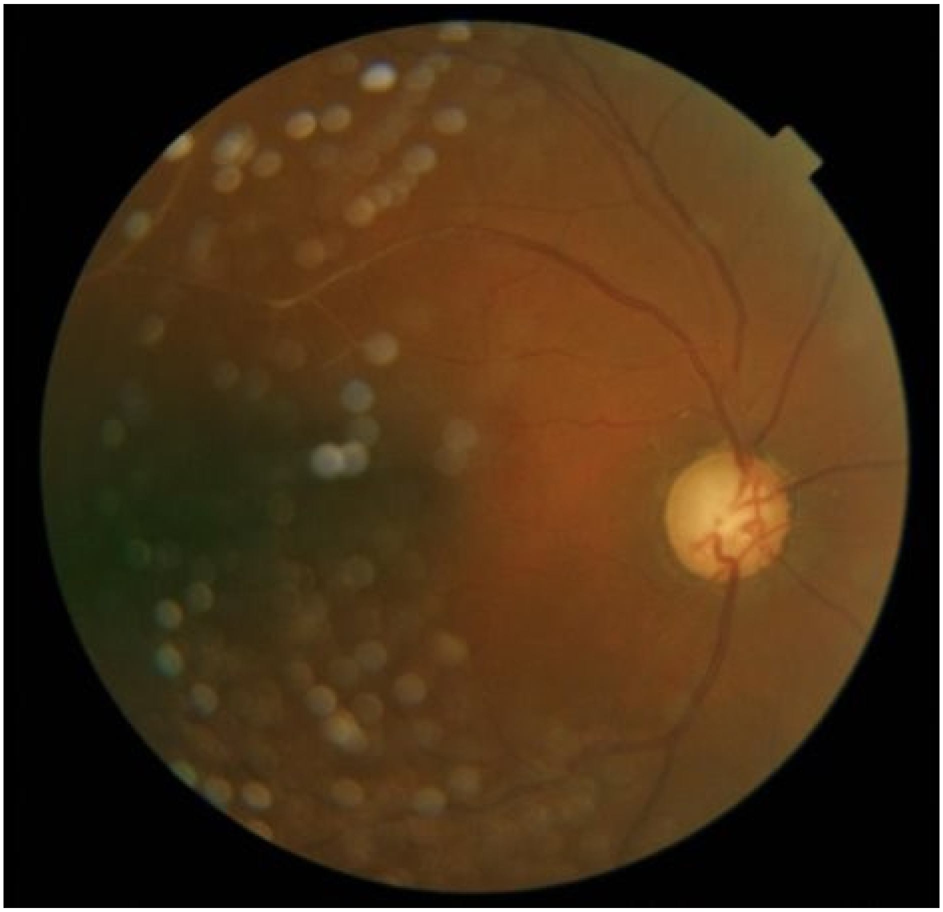


Figure 7. Example of image graded (score of 1), which indicated low quality with no or almost no findings observable (with or without significant glare or visual artifact).

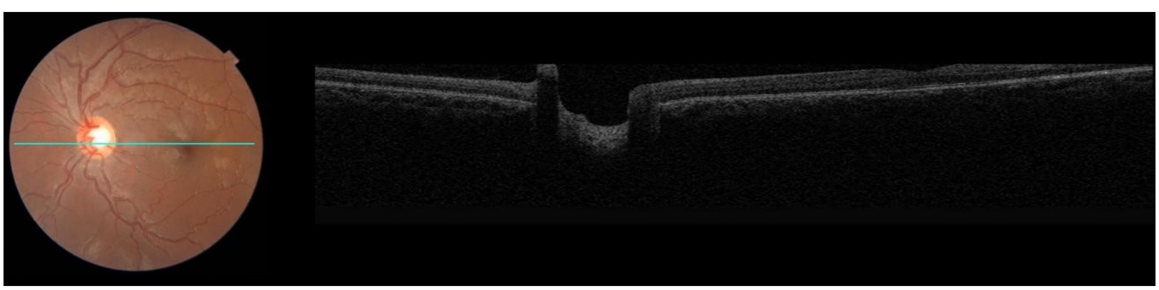


Figure 8. Example of image graded (score of 3), which indicate good quality with all observable findings.

3.4 Resident Experience Feedback (Survey)

The residents were given a survey (Supplemental Table A) and asked to rate the device's features based on ease of use, technical performance, image quality and educational benefit. Responses were scored on a scale of 1 to 10 (lowest to highest) or on a scale of “Strongly Disagree” to “Strongly Agree” and were then recoded to a 1 to 5 scale. The survey was completed by 8 out of 10 residents who used the device to examine the patients.

Table 3 shows the survey results. Half of the residents used the device more than 10 times per month (n=4), while 2 residents reported usage of 5 to 10 times per month. The remaining 2 reported using it 1 to 5 times a month. Residents documented that they most often utilized the fundus photo of the disc or macula feature (n=7), followed by macular OCT (n=6), followed by fundus photo of peripheral views of the retina (n=2) and optic nerve (n=2). In terms of residents’ experience with various aspects of the device (on a scale of 1 low to 10 high), residents rated patient comfort at a 9 (SD .9), quality of images at a 7.3 (SD 2.1), ease of use at a 6.4 (SD 2.4), and technical reliability at a 5 (SD 2.8). Looking at the clinical workflow and educational aspect of the device, all residents reported that they would use the device again in the future (n=4). The latter statement was only asked of four residents as it was added on at a later time point in our study. Most residents (n=7) reported that the Topcon device allowed for a more accurate diagnosis. Only half of the residents (n=4) think the Topcon device is easy to use. Two of the residents reported that the Topcon device hindered clinical workflow. Of eight residents, six reported that they changed their diagnosis after using the device 0% to 25% of the time; one resident reported changing ther diagnosis after using it 25% to 50% of the time, and one additional resident reported that using the device changed the diagnosis 50% to 75% of the time. All residents shared images with a supervising ophthalmologist, with the most common method being a cellphone picture (n=8), followed by sharing the patient's medical record number (MRN) (n=3) so the attending/fellow could look up the image remotely in the EHR. Finally, one resident reported physically showing the image on the Topcon computer screen to supervising ophthalmologists.

In open-ended questions, residents mentioned a multitude of challenges with the device. According to one resident, "There [were] numerous challenges through[out] the year, with [an] inability to log in, being unable to find the patient in the worklist, machine malfunction, [and] lack of good manual OCT adjustment tools in patients with media opacities." Residents also reported that the device had other shortcomings, including images with a lot of artifacts and, in some cases, images that could only be taken on one eye of a patient. They also reported several difficulties linking the Topcon device to the hospital systems and platforms. Three residents reported problems synchronizing the system to Epic, the hospital's EHR. According to one resident, "Epic workflow can be cumbersome and not work at times." A resident stated issues with uploading images to the Zeiss Forum application (the WEI image-sharing platform), and even when images were successfully uploaded, images had a "blue hue" (**Figure 9**).

Residents also experienced connectivity problems when connecting the Topcon device to the independent computer that runs the image viewer and uploader application. According to one resident, these issues were fixed half of the time by closing out of the program and signing back in. However, “even when it does fix the problem, it adds a lot of extra time to the whole process.”

Table 3. Summary of survey responses of first-year ophthalmology residents using the Topcon 3D OCT-1 Maestro system.

Resident Experience with the Topcon device	
Usage per month	
1-5 times, n (%)	2 (25)
5-10 times, n	2 (25)
10+ times, n	4 (50)
Features used	
Fundus photo of disc or macula, n (%)	7 (87.5)
Fundus photo of peripheral views of retina, n (%)	2 (25)
Anterior segment OCT, n (%)	1 (12.5)
Optic nerve OCT, n (%)	2 (25)
Macular OCT, n (%)	6 (75)
Technical features (graded on a scale of 1 [least favorable] to 10 [most favorable])	
Ease of use, mean (SD)	6.4 (2.4)
Technical reliability, mean (SD)	5 (2.8)
Quality of images, mean (SD)	7.3 (2.1)
Resident perception of patient comfort, mean (SD)	9 (0.9)
Educational features/Clinical workflow (graded on a scale of "Strongly Disagree" to "Strongly Agree," but recoded respectively to a scale of 1-5)	
Device allowed a more accurate diagnosis, mean (SD)	4.1 (1.0)
Device is easy to use, mean (SD)	3.3 (1.3)
Device hindered clinical workflow, mean (SD)	2.8 (0.9)
How often a diagnosis changed after using the device	
0 - 25% of the time, n (%)	6 (75)
25 - 50% of the time, n (%)	1 (12.5)
50 - 75% of the time, n (%)	1 (12.5)
75 - 100% of the time, n (%)	0
Were images shared with a superior?	
Yes, n	8
No, n	0

n = number of survey respondents; OCT = optical coherence tomography; SD = standard deviation
[*] These features were on a scale of "Strongly Disagree" to "Strongly Agree," but recoded respectively to a scale of 1-5

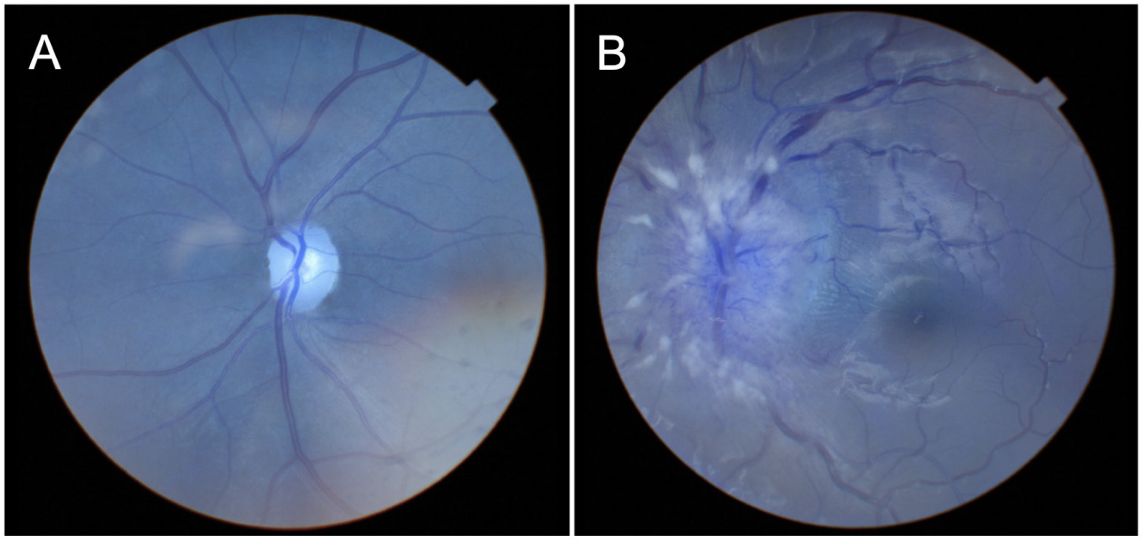


Figure 9: Two examples of blue-tinted images of the fundus. Image A was taken in a patient who was worked up for a sellar mass. Image B was taken in a patient who was evaluated for papilledema.

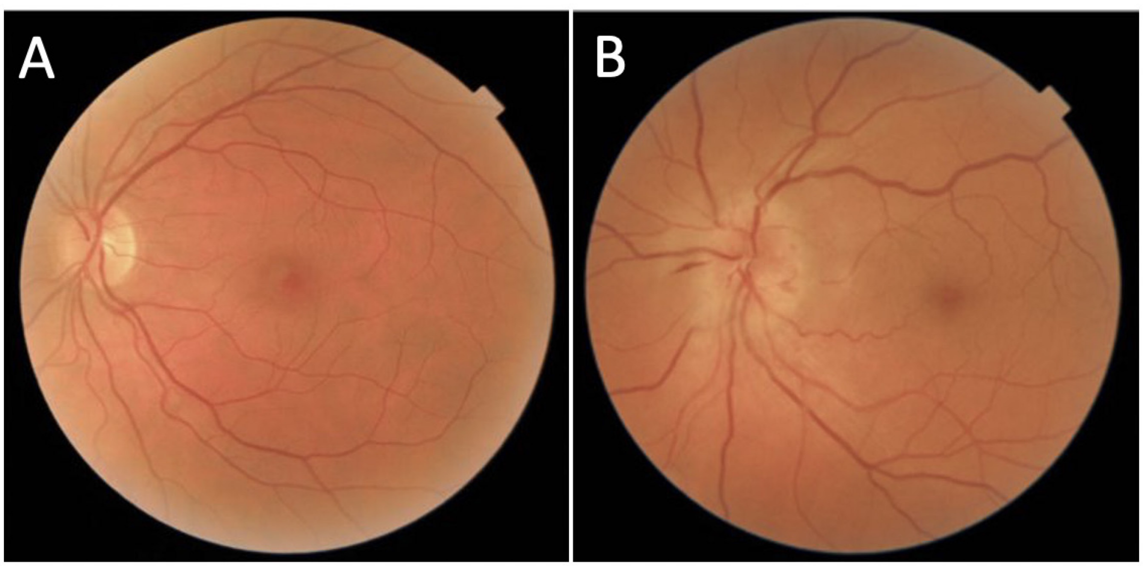


Figure 3: Two examples of fundus photos. Image A was taken in a patient who had a normal fundus. Image B was taken in a patient who was evaluated for papilledema**.**

4. DISCUSSION

4.1 General Discussion of Results

This pilot study evaluated the feasibility and acceptance of the teleophthalmology tool in the ED setting. Based on this study, we have found that teleophthalmology was feasible in the ED setting in that all residents in this study completed their assessment and were able to reach a conclusion. We have found that all residents reported that they would use the device again in the future, demonstrating a high level of acceptance. Recognizing the Topcon device's most common uses in ED setting is essential in identifying future cohorts for randomized controlled trials and evaluating the impact of teleophthalmology in ED settings. It also shows the device’s value in diagnostic accuracy in improving resident education. In this study, we found out that papilledema was the most common diagnosis when a teleophthalmology fundus and OCT camera were used in the ED setting.

Based on the survey responses, we found that using teleophthalmology in the ED setting was perceived by residents as beneficial in their education and, based on image review, it enhanced diagnostic accuracy. Nevertheless, residents experienced several technical issues while working on the device, which in some cases hindered the clinical workflow. Addressing technical challenges before further use of teleophthalmology can be valuable in the ED setting or any other clinical practice. Demographics show a higher percentage of White (43%) and Black (39%) patients over other races. Teleophthalmology in our study was mostly used to evaluate papilledema (18.6%), given the importance of viewing the optic nerve and measuring the severity of swelling to avoid blindness if not treated in a timely manner. Regarding the length of stay in the ED, Topcon device use did not correlate with a longer length of stay, although there was a small difference in favor of a non- Topcon examination (9.3 [SD 7.6, range 0.3 – 51.8] vs. 7.9 (SD 7.3 [range 0.7 – 92.4] hours, p = 0.07). One reason could be those patients with severe and complex conditions were more likely to require imaging and were thus more likely to remain in the hospital for a longer period of time. Patients were assessed based on their diagnosis. Patients who were examined for papilledema, the most frequent condition in our cohort, also did not have a difference in length of stay, meaning that the Topcon system is effective without increasing hospitalization time for patients. Overall image quality was low (1.79 out of 3) due to multiple attempts by residents to capture high-quality images. Survey results demonstrate high utilization of the device by residents. The majority of the residents used the device 10 times or more. This shows high interest and high efficacy of teleophthalmology based on resident feedback. Even though all residents reported that they would use the device again in the future, they reported many challenges encountered. In some cases, it hindered the clinical workflow.

When we find the outcomes are effective in the target study, the project can be extended in a multitude of settings. Expansion may include the implementation of real-time video consultation to improve ED screening and triage at non-academic community hospitals that do not have access to local ophthalmology consultation services. Additionally, teleophthalmology tools could be utilized more often to treat and monitor ophthalmic patients in the ED by resident physicians of other specialties as mentioned above. In addition to improving resident education, the next phase of implementation of the program can include studying how to reduce length of stay of patients who present with urgent ophthalmic conditions in the ED, with a special focus on patient outcomes and patient and resident satisfaction scores. The pilot study we present also will inform future studies by demonstrating the specific ophthalmic diagnoses for which our teleophthalmology device was used most often by the residents; as a result, we can develop future studies that focus on these most common diagnoses.

4.2 Comparison with Prior Work

To our knowledge, this is the first study to assess images captured by residents and the effect of teleophthalmology on residents' educational performance. Previous studies have demonstrated efficacy in using teleophthalmology fundus photography in the diagnosis of complex diseases such as diabetic retinopathy, retinopathy of prematurity, age-related macular degeneration, glaucoma, and trauma.[70] The efficacy of teleophthalmology in the ED setting was illustrated by a clinical trial in the ED (FOTO-ED) comparing fundus photography versus ophthalmoscopy outcomes. Biousse and colleagues found that non-mydriatic ocular fundus photographs were significantly more sensitive for detecting relevant abnormalities than direct ophthalmoscopy [71]. A study at the University of Pittsburgh Medical Center of 50 patients showed teleophthalmology was reliable and efficient for triaging patients in the ED settings.[72] The published studies on the use of teleophthalmology in improving resident education are limited. A study at Tel Aviv University evaluated residents' education by having the residents use a slit-lamp connected to a video camera.[73] The resident records the video and shares it with a senior physician by email. A real-time telephone call was conducted to discuss the complicated cases during night shifts in the ED. In all 49 cases, there was 100% agreement between the diagnosis made by the resident during nighttime shift examination and the on-site examination made by the senior ophthalmologist the following day. In addition, 48 patients (98%) stated that their next visit to the emergency room would favor the telemedicine test rather than the on-site examination. Our pilot study demonstrates important findings of teleophthalmology in the ED settings in terms of the diverse patient demographics, different uses of the device, educational aspects, and challenges encountered by our residents. Presenting the uses of this device at a well-known academic eye center such as WEI and identifying the most common application for this device is clinically important. It will allow us to further tailor the application for the use of teleophthalmology for residents' education and patient benefits.

4.3 Teleophthalmology in the Post COVID-19 Era

The coronavirus disease (COVID-19) pandemic changed how clinicians provide care to patients.[74] On March 18, 2020, the American Academy of Ophthalmology (AAO) asked ophthalmologists around the country to refrain from providing non-emergent in-person visits.[75] Most ophthalmologists were forced to shift to televisit. However, according to a study conducted by Kellogg Eye Center at the University of Michigan, most ophthalmic clinicians (n=58; 66.2%) felt at least somewhat confident about using teleophthalmology during the COVID-19 pandemic. Most clinicians (59.8%) believed they would continue using teleophthalmology to provide services for the patients in the future. Patient acceptance is the most critical part of the utilization process. If patients feel confident in the teleophthalmology tool, this confidence will increase the adoption rate among providers, as providers will try to maximize their services to meet patients' needs. According to a recent survey of 1,000 ophthalmology patients, approximately 3 out of 4 patients had a virtual visit during the COVID-19 pandemic. The majority (75%) of these patients were extremely satisfied with their experience.[76] Knowing the current evidence of physicians/patient acceptance rates, leaders, educators, healthcare professionals, and other stakeholders in the ophthalmology specialty should consider identifying the required policies and procedures to increase patient access to teleophthalmology care and ensure a high patient satisfaction experience.[77]

Even though there are complexities in performing the entire ophthalmic examination online, tools like the camera used in our pilot study show the promise of improving communication in distance between healthcare providers, allowing advanced visual detail for better analysis and more accurate diagnosis.

4.4 Implications for Practice and Further Research

The findings in this study imply several recommendations for future research concerning the use of teleophthalmology in the ED setting. First, the finding that the diagnosis found in our cohort do not represent the most prevalent diagnoses in the general population (e.g., cataract, glaucoma, and dry eyes) due to the lack of necessity for a fundus photo or OCT for those diagnoses. Second, the findings indicate that there is a need for better training on using such technology with advanced features while taking into consideration that the training will not lead to physician burnout. Third, the majority of residents stated that teleophthalmology helped them diagnose patients more accurately and that they would use the device again in the clinical practice. These findings mean that residents have the desire to acquire a technical skill if it improves their clinical outcomes. Fourth, the findings also illustrate that teleophthalmology probably increased residents' education by allowing them to discuss a differential diagnosis with the consultant instantly instead of having to wait for the senior consultant to come to examine the patient themselves. In addition, teleophthalmology allowed the resident to participate in practice-based education. Finally, poor image quality was one of the technical concerns for us. On average, images showed poor to fair quality, although the best image of each patient visit was much better quality (fair to good). One reason for the low average image quality could be that residents needed to try multiple attempts to get a high-quality image of the patient's eye due to image artifacts or bad patient positioning. This reasoning may also clarify the high number of images (eight images per patient) taken per patient. Overall, the residents were positive about the experience and showed interest in using teleophthalmology in the future.

Based on the findings from this study, we recommend that future studies start first in assessing the technical issues of teleophthalmology devices, including the integration with other platforms and technical features related to the use of the device. The residents' readiness and training to work with such a device should be evaluated prior to a randomized clinical trial. Future studies should include a randomized clinical trial focused on evaluating residents' diagnosis accuracy, assessment of residents' education (pre-and post-assessment to quantify residents' educational outcomes), patient satisfaction; and ED performance, including the patient's length of stay and outcomes improvement.

4.5 Strengths and Limitations of the Study

This study has several strengths. First, the pilot study presented data from an ED center well-known for diverse patient demographics and diverse clinical cases. Second, this study presented a full year of data during a critical time such as the COVID-19 pandemic. Third, this study presented different uses of teleophthalmology features for a variety of diagnoses. Finally, this study illustrated the educational aspects of residents' experience with the device and the challenges encountered while using the device. Despite the potential contributions of the present study, some limitations must be considered. First, because of the retrospective observational nature of the study, we were unable to randomize the use of teleophthalmology and assess the quantitative effect on resident education. Second, this study looked at patients from only one ED center, which restricts the generalizability of our results and the main findings.

5. CONCLUSIONS

Teleophthalmology tools in our residency program are shown to be a potentially effective tool to diagnose complex cases by residents, reduce the wait time for a senior consultant and engage residents in practice-based education. Even though our study's findings did not quantify the effect on resident education nor measured the diagnosis accuracy improvement quantitatively, it provided a full year of data on teleophthalmology utilization and residents' experience and their feedback. As the COVID-19 pandemic advances, these findings could be useful in guiding other specialties as they start to implement telemedicine programs and evaluate residency education programs.

6. APPENDIX

Supplemental Table A: Survey administered to first-year ophthalmology residents regarding their experience with the Maestro 3D OCT-1 system (Topcon Medical Systems Inc., Oakland, NJ, USA).

What year are you in residency?

- First year (PGY-2)
- Second year (PGY-3)

On an average month, how many times did you use the Topcon Fundus camera to obtain images on a patient you were
working up in the ED?

- 1-5 times
- 5-10 times
- 10+ times

What feature on the Topcon Fundus camera device have you used? (select all that may apply)

- Fundus photo of disc or macula
- Fundus photo of peripheral views of retina
- Anterior segment OCT
- Optic nerve OCT
- Macular OCT
- External photograph (anterior segment)
- Other

How would you rate the following features of the Topcon device? (1 lowest, 10 highest)

- Ease of use
- Technical reliability
- Quality of images obtained
- Patient comfort

Please rate your agreement with the statement: "The Topcon device allowed me to diagnose patients more accurately."

- Strongly Disagree
- Disagree
- Neither agree or disagree
- Agree
- Strongly Agree

Please rate your agreement with the statement: "The Topcon device is easy to use."

- Strongly Disagree
- Disagree
- Neither agree or disagree
- Agree
- Strongly Agree

Please rate your agreement with the statement: "Use of the Topcon device hindered my clinical workflow."

- Strongly Disagree

Disagree
Neither agree or disagree
Agree
Strongly Agree

Please rate your agreement with the statement: "I would use the Topcon device again in the future."

Strongly Disagree
Disagree
Neither agree or disagree
Agree
Strongly Agree

How often did you change your diagnosis after using the Topcon camera?

0-25% of the time
25-50% of the time
50-75% of the time
75-100% of the time

Did you ever share images that you obtained on the Topcon device with a superior (i.e. a senior resident, fellow, or an attending?)

No
Yes

Did you face any technical challenges or obstacles while using the Topcon Fundus Camera? (Text answer)

Do you have any suggestions to further improve the Topcon Fundus Camera experience? (Text answer)

n = Number of survey respondents
SD = Standard deviation
OCT = Optical coherence tomography

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